



INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification ⁶ : H01L 29/772, 29/812, 29/205, 21/335, 21/20</p>	<p>A1</p>	<p>(11) International Publication Number: WO 99/66562 (43) International Publication Date: 23 December 1999 (23.12.99)</p>
<p>(21) International Application Number: PCT/GB99/01940 (22) International Filing Date: 18 June 1999 (18.06.99) (30) Priority Data: 9813142.8 19 June 1998 (19.06.98) GB (71) Applicant (for all designated States except US): THE SECRETARY OF STATE FOR DEFENCE [GB/GB]; Defence Evaluation and Research Agency, Farnborough, Hampshire GU14 0LX (GB). (72) Inventors; and (75) Inventors/Applicants (for US only): JEFFERSON, John, Henry [GB/GB]; DERA Malvern, St. Andrews Road, Malvern, Worcestershire WR14 3PS (GB). PHILLIPS, Timothy, Jonathan [GB/GB]; DERA Malvern, St. Andrews Road, Malvern, Worcestershire WR14 3PS (GB). (74) Agent: BARKER, Brettell; 138 Hagley Road, Edgbaston, Birmingham B16 9PW (GB).</p>		<p>(81) Designated States: CN, GB, JP, KR, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE). Published <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p>
<p>(54) Title: QUANTUM WIRE FIELD-EFFECT TRANSISTOR AND METHOD OF MAKING THE SAME</p> <div> </div> <p>(57) Abstract</p> <p>A quantum wire field-effect transistor having at least one, one-dimensional, elongate conducting means (14) provided by at least a first semiconductor layer surrounded by a wider bandgap, second semiconductor layer (12, 13) and extending between source (24) and drain (26) electrodes, and in which there is provided a backgate structure (8, 23) to control conduction in the elongate conducting means. The transistor can be a Single Electron Transistor (SET) wherein two adjacent gate electrodes (16, 18) are disposed over the elongate conducting means to induce a quantum dot (17) therein, and it can be made with the first semiconductor layer material as GaAs and the second semiconductor layer material as AlGaAs. A method of making the transistor involves preferentially growing the elongate conducting means at the bottom of a groove (6) lined with the second semiconductor layer (12).</p>		

P...ENT COOPERATION TREATY

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NOTIFICATION OF ELECTION

(PCT Rule 61.2)

From the INTERNATIONAL BUREAU

To:

Assistant Commissioner for Patents
United States Patent and Trademark
Office
Box PCT
Washington, D.C.20231
ÉTATS-UNIS D'AMÉRIQUE

in its capacity as elected Office

Date of mailing (day/month/year) 10 February 2000 (10.02.00)	
International application No. PCT/GB99/01940	Applicant's or agent's file reference JL2156
International filing date (day/month/year) 18 June 1999 (18.06.99)	Priority date (day/month/year) 19 June 1998 (19.06.98)
Applicant JEFFERSON, John, Henry et al	

1. The designated Office is hereby notified of its election made:

☒ in the demand filed with the International Preliminary Examining Authority on:
10 January 2000 (10.01.00)

☐ in a notice effecting later election filed with the International Bureau on:

2. The election ☒ was

☐ was not

made before the expiration of 19 months from the priority date or, where Rule 32 applies, within the time limit under Rule 32.2(b).

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland	Authorized officer Olivia RANAIVOJAONA
Facsimile No.: (41-22) 740.14.35	Telephone No.: (41-22) 338.83.38

PATENT COOPERATION TREATY

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NOTIFICATION THAT INTERNATIONAL
APPLICATION CONSIDERED TO BE
WITHDRAWN

(PCT Article 14(1), (3) or (4) and Rule 29.1)

From the INTERNATIONAL BUREAU

To:

Assistant Commissioner for Patents
United States Patent and Trademark
Office
Box PCT
Washington, D.C.20231
ÉTATS-UNIS D'AMÉRIQUE

in its capacity as designated Office

Date of mailing (day/month/year) 24 September 1999 (24.09.99)	IMPORTANT NOTIFICATION
International application No. PCT/GB99/01980	International filing date (day/month/year) 23 June 1999 (23.06.99)
Applicant MARS U.K. LIMITED et al	

1. The International Bureau hereby gives notice that the receiving Office has, on the date indicated below, notified to the applicant that the international application is to be considered withdrawn:

07 September 1999 (07.09.99)

2. ☐ A copy of this notification has been sent to the International Preliminary Examining Authority.

The International Bureau of WIPO 34, chemin des Colombettes 1211 Geneva 20, Switzerland Facsimile No.: (41-22) 740.14.35	Authorized officer F. Gateau Telephone No.: (41-22) 338.83.38
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INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference JL2156	FOR FURTHER ACTION see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/GB 99/ 01940	International filing date (day/month/year) 18/06/1999	(Earliest) Priority Date (day/month/year) 19/06/1998
Applicant THE SECRETARY OF STATE FOR DEFENCE et al.		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 4 sheets.

☒ It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

- a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.
- ☐ the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).
- b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :
- ☐ contained in the international application in written form.
- ☐ filed together with the international application in computer readable form.
- ☐ furnished subsequently to this Authority in written form.
- ☐ furnished subsequently to this Authority in computer readable form.
- ☐ the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
- ☐ the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished
2. ☐ **Certain claims were found unsearchable** (See Box I).
3. ☐ **Unity of invention is lacking** (see Box II).

4. With regard to the title,

- ☐ the text is approved as submitted by the applicant.
- ☒ the text has been established by this Authority to read as follows:

QUANTUM WIRE FIELD-EFFECT TRANSISTOR AND METHOD OF MAKING THE SAME

5. With regard to the abstract,

- ☐ the text is approved as submitted by the applicant.
- ☒ the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the drawings to be published with the abstract is Figure No.

- ☒ as suggested by the applicant. 2
- ☐ because the applicant failed to suggest a figure. ☐ None of the figures.
- ☐ because this figure better characterizes the invention.

Box III TEXT OF THE ABSTRACT (Continuation of item 5 of the first sheet)

The Abstract should be amended as follows;
A quantum wire field-effect transistor having at least one, one-dimensional, elongate conducting means (14) provided by at least a first semiconductor layer surrounded by a wider bandgap, second semiconductor layer (12,13) and extending between source (24) and drain (26) electrodes, and in which there is provided a backgate structure (8,23) to control conduction in the elongate conducting means. The transistor can be a Single Electron Transistor (SET) wherein two adjacent gate electrodes (16,18) are disposed over the elongate conducting means to induce a quantum dot (17) therein, and it can be made with the first semiconductor layer material as GaAs and the second semiconductor layer material as AlGaAs. A method of making the transistor involves preferentially growing the elongate conducting means at the bottom of a groove (6) lined with the second semiconductor layer (12).

A. CLASSIFICATION OF SUBJECT MATTER IPC 6 H01L29/772 H01L29/812 H01L29/205 H01L21/335 H01L21/20				
According to International Patent Classification (IPC) or to both national classification and IPC				
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) IPC 6 H01L				
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched				
Electronic data base consulted during the international search (name of data base and, where practical, search terms used)				
C. DOCUMENTS CONSIDERED TO BE RELEVANT				
Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.		
X	EP 0 386 388 A (IBM CORP) 12 September 1990 (1990-09-12)	1-4, 6, 7, 9, 10, 15, 16, 21-23, 25-27, 32, 33, 38, 39		
Y	column 5, line 3 -column 8, line 50; figures 1-3	5, 8, 11-14, 17-20, 24, 28-31, 34-37		
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<input checked="" type="checkbox"/> Further documents are listed in the continuation of box C. <input checked="" type="checkbox"/> Patent family members are listed in annex.				
° Special categories of cited documents :				
<table style="width: 100%; border: none;"> <tr> <td style="width: 50%; vertical-align: top; border: none;"> "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed </td> <td style="width: 50%; vertical-align: top; border: none;"> "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family </td> </tr> </table>			"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family
"A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier document but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art. "&" document member of the same patent family			
Date of the actual completion of the international search <div style="text-align: center; font-weight: bold;">1 October 1999</div>		Date of mailing of the international search report <div style="text-align: center; font-weight: bold;">13/10/1999</div>		
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016		Authorized officer <div style="text-align: center; font-weight: bold;">Morvan, D</div>		

INTERNATIONAL SEARCH REPORT

International Application No

T/GB 99/01940

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WANG X-L ET AL: "FLOW RATE MODULATION EPITAXY OF ALGAAS/GAAS QUANTUM WIRES ON NONPLANAR SUBSTRATE" APPLIED PHYSICS LETTERS, vol. 66, no. 12, 20 March 1995 (1995-03-20), pages 1506-1508, XP000500907 ISSN: 0003-6951 page 1507, right-hand column, line 30 -page 1508, left-hand column, line 13; figure 4A ---	5, 17-19, 28-31
Y	WO 89 07832 A (BELL COMMUNICATIONS RES ET AL) 24 August 1989 (1989-08-24) page 5, line 2 -page 6, line 17; figures 1-4 ---	8, 34-36
A		11, 20, 37
Y	GB 2 295 272 A (TOSHIBA CAMBRIDGE RES CENTER) 22 May 1996 (1996-05-22) page 2, line 25 -page 4, line 15 page 6, line 4 -page 8, line 9; figures 1-3 -----	11-14, 20, 24, 37

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

T/GB 99/01940

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
EP 0386388	A	12-09-1990	CA 2006266 A,C JP 2266514 A US 5037776 A	10-09-1990 31-10-1990 06-08-1991
WO 8907832	A	24-08-1989	CA 1315865 A US 4974036 A US 5040032 A	06-04-1993 27-11-1990 13-08-1991
GB 2295272	A	22-05-1996	JP 9051106 A US 5701017 A	18-02-1997 23-12-1997



REC'D 18 SEP 2000

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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference JL2156		FOR FURTHER ACTION See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/GB99/01940	International filing date (day/month/year) 18/06/1999	Priority date (day/month/year) 19/06/1998	
International Patent Classification (IPC) or national classification and IPC H01L29/772			
Applicant THE SECRETARY OF STATE FOR DEFENCE et al.			
<p>1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.</p> <p>2. This REPORT consists of a total of 7 sheets, including this cover sheet.</p> <p><input checked="" type="checkbox"/> This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).</p> <p>These annexes consist of a total of 5 sheets.</p>			
<p>3. This report contains indications relating to the following items:</p> <ul style="list-style-type: none"> I <input checked="" type="checkbox"/> Basis of the report II <input type="checkbox"/> Priority III <input type="checkbox"/> Non-establishment of opinion with regard to novelty, inventive step and industrial applicability IV <input type="checkbox"/> Lack of unity of invention V <input checked="" type="checkbox"/> Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement VI <input type="checkbox"/> Certain documents cited VII <input checked="" type="checkbox"/> Certain defects in the international application VIII <input checked="" type="checkbox"/> Certain observations on the international application 			
Date of submission of the demand 10/01/2000		Date of completion of this report 14.09.2000	
Name and mailing address of the international preliminary examining authority:  European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465		Authorized officer Morvan, D Telephone No. +49 89 2399 2258 	

**INTERNATIONAL PRELIMINARY
EXAMINATION REPORT**

International application No. PCT/GB99/01940

I. Basis of the report

1. This report has been drawn on the basis of *(substitute sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to the report since they do not contain amendments.)*:

Description, pages:

1-15 as originally filed

Claims, No.:

1-32 with telefax of 12/07/2000

Drawings, sheets:

1-4 as originally filed

2. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
☐ the claims, Nos.:
☐ the drawings, sheets:

3. ☒ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

see separate sheet

4. Additional observations, if necessary:

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB99/01940

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	2, 3, 5, 7, 9-12, 15-18, 21-23, 27-32
	No:	Claims	1, 4, 6, 8, 13, 14, 19, 20, 24, 25, 26
Inventive step (IS)	Yes:	Claims	
	No:	Claims	1-32
Industrial applicability (IA)	Yes:	Claims	1-32
	No:	Claims	

2. Citations and explanations

see separate sheet

VII. Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

see separate sheet

VIII. Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

see separate sheet

Regarding Section I:

The set of claims does not meet the requirements of Article 34(2)(b) PCT since the amendments dated 12/07/00 introduce subject-matter which extends beyond the content of the application as filed:

1. The feature of claim 1 stating that **at least one wall** of the groove is a substantially planar surface, roughly parallel to a crystal plane on which the growth rate of the first semiconductor is substantially zero cannot be derived as such from the original application documents, see in this respect figures 2 and 4 and original page 8, lines 13-25 and original page 12, line 16 - original page 13, line 3, also the additional feature of dependent claim 2, which is properly supported by the original disclosure.
A similar objection applies to the corresponding method feature of independent claim 19.
2. There is no basis either in the original application documents for the feature of claim 31 disclosing that quantum dots are provided in the vicinity of **stops due to** the thickness variations of the conducting means due to the off axis groove (it is noted that this would hold true if "steps" was used in lieu of "stops"), see in this respect page 9, lines 15-24.

Therefore, the amendments at issue have been disregarded under Rule 70.2(c) PCT.

Regarding Section V:

1. Reference is made to the following documents:

D1 = EP-A-0 386 388

D2 = Applied Physics Letters, vol. 66, no. 12, 20 March 1995, pages 1506-1508 (Wang et al.)

D3 = WO 89/07832

D4 = GB-A-2 295 272

2. Insofar as the present text can be understood (see item VIII in this respect), the subject-matter of claims 1, 4, 6, 8, 13, 14, 19, 20, 24, 25 and 26 is not new in the sense of Rule 64(1)-(3) PCT, contrary to the requirements of Article 33(2) PCT:

- 2.1 D1 (see column 5, line 3 - column 8, line 50 and figures 1-3) discloses a transistor having at least one, substantially one-dimensional, elongate conducting means provided by at least a first semiconductor (InGaAs (14; 24; 34, 36, 38)) substantially surrounded by a second semiconductor (InP (13, 15; 23, 25; 33, 35, 37, 39)) and extending between source and drain electrodes (26, 28), and in which there is provided at least one further electrode (27) in a region of the elongate conducting means. Furthermore, in the transistor of D1, the elongate conducting means are provided in a groove within the second semiconductor (adjacent the groove in the substrate).

Hence, all the features of claim 1 are known from D1 and the subject-matter of claim 1 is not new.

- 2.2 Furthermore, D1 (see the aforementioned passages, in particular figures 1(A)- 1(G) and the corresponding text) also discloses a method of providing a transistor comprising providing a substantially one-dimensional elongate conducting means by providing a first semiconductor (InGaAs (14; 24; 34, 36, 38)) substantially surrounded by a second semiconductor material (InP (13, 15; 23, 25; 33, 35, 37, 39)), providing a source electrode (26) at a first end region of the conducting means and a drain electrode (28) at a second end region of the conducting means, and providing at least one further gate electrode (27) in a region of the conducting means. Furthermore, the elongate conducting means are provided by creating a groove of second

semiconductor and subsequently providing the first semiconductor in the groove.

Hence, all the features of independent claim 19 are also known from D1. Therefore, the subject-matter of independent claim 19 is not new either.

2.3 The additional features of dependent claims 4, 6, 8, 13, 14, 20, 24, 25 and 26 are moreover obviously also known from D1.

Therefore, the subject-matter of dependent claims 4, 6, 8, 13, 14, 20, 24, 25 and 26 is not new either.

3. Furthermore, insofar as the present text can be understood (see item VIII in this respect), the subject-matter of claims 2, 3, 5, 7, 9-12, 15-18, 21-23 and 27-32 does not involve an inventive step in the sense of Rule 65(1)-(2) PCT, contrary to the requirements of Article 33(3) PCT:

3.1 The additional features of dependent claims 2 and 3 would be regarded by the skilled person as relating to a mere technical equivalent to the configuration dealt with in D1, which can be interchanged with said configuration where circumstances make it desirable, see in this respect D1, column 6, lines 29-35 and D2, page 1507, right-hand column, line 30 - page 1508, left-hand column, line 13 and figure 4(a).

Hence, the subject-matter of dependent claims 2 and 3 lacks the required inventive step.

3.2 The additional features of dependent claims 5, 7, 9-12, 15-18, 21-23 and 27-32 are merely normal design options in the present technical field (see in particular eg. D2, page 1507, right-hand column, line 30 - page 1508, left-hand column, line 13 and figure 4(a) regarding claims 5, 15-17, 22 and 27-29; D3, page 5, line 2 - page 6, line 17 and figures 1-4 regarding claims 9, 18 and 30-32; D4, page 2, line 25 - page 4, line 15, also page 6, line 4 - page 8, line 9 and figures 1-3 regarding claims 9, 10, 12, 18, 21 and 32). The skilled person would therefore readily consider including said features in the transistor and method known from D1.

Hence, the subject-matter of dependent claims 5, 7, 9-12, 15-18, 21-23 and 27-32 does not involve an inventive step.

4. The subject-matter of claims 1-32 is obviously susceptible of industrial application.

Regarding Section VII:

The following deficiencies have been noticed:

1. Contrary to the requirements of Rule 5.1(a)(ii) PCT, the relevant background art disclosed in the documents D1 to D4 is not mentioned in the description, nor are these documents identified therein.
2. The features of the claims are not provided with reference signs placed in parentheses, contrary to the requirements of Rule 6.2(b) PCT.

Regarding Section VIII:

The present application does not meet the requirements of Article 6 PCT because claims 1, 2, 5, 12, 13, 19, 22, 29 and 31 are not clear:

1. The term "substantially" used in claims 1, 2, 5, 13, 19, 22, 29 and 31 is vague and unclear and leaves the reader in doubt as to the meaning of the technical features to which it refers, thereby rendering the definition of the subject-matter of said claims unclear.
A similar objection applies to the unclear expression "hard confinement" used in claim 12 and to the term "stops" used in claim 31.